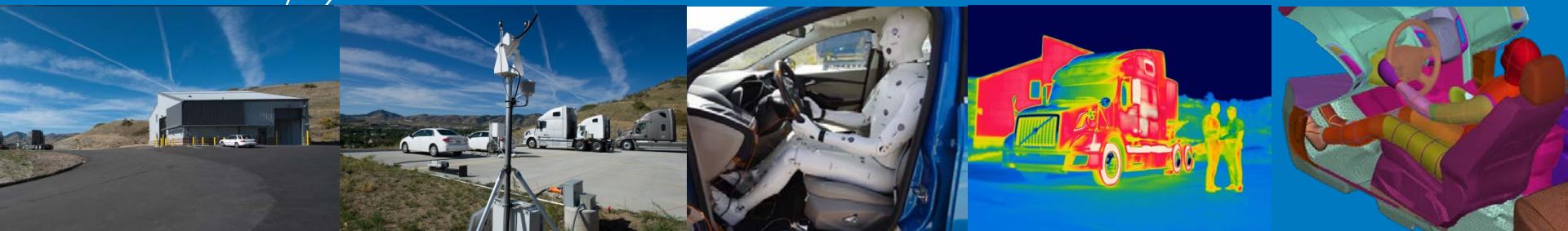


# Design and Implementation of a Thermal Load Reduction System in a Hyundai Sonata PHEV



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**John Rugh, Task Leader**  
**National Renewable Energy Laboratory**  
**June 9, 2015**

Project ID: VSS165

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

# Overview

## Timeline

- **Project start date:** FY15
- **Project end date:** FY17
- **Percent complete:** 7%

## Budget

### *Fully Funded FOA Project*

- **Total project funding: \$3,054,817**
  - DOE share: \$ 2,443,790
  - Contractor share\*: \$ 611,027
- **Funding received in FY14: \$ 2,443,790**
- **Funding for FY15: \$ 0**

*\* Contractor share represents 20% cost share for the project*

## Barriers

- **Risk Aversion:** *Manufacturers are reluctant to invest in and introduce new technologies*
- **Cost:** *Effective, timely evaluation of advanced vehicular components and configurations is needed.*
- **Range Anxiety:** *Large climate control loads can contribute significantly to electric drive vehicle (EDV) range anxiety*

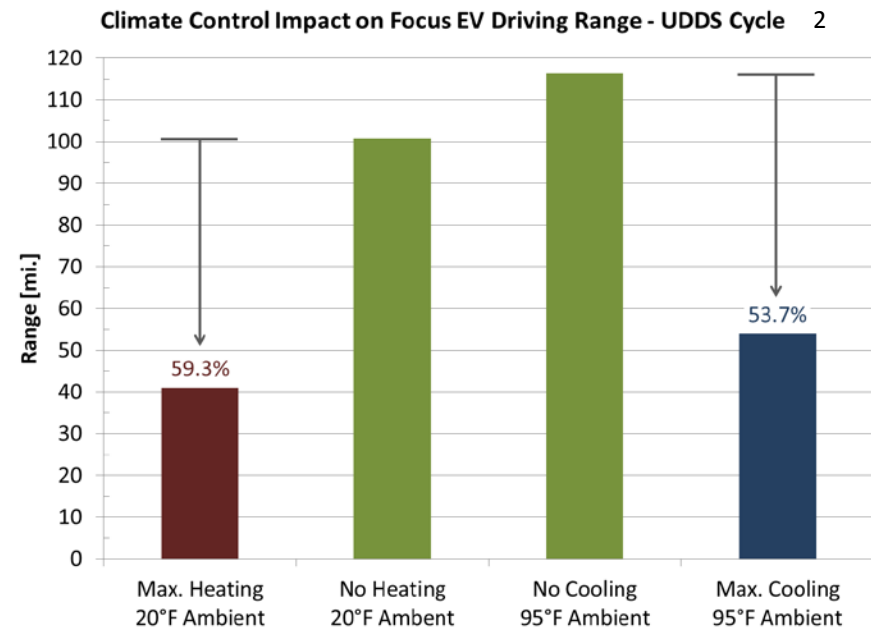
## Partners

- **Interactions/collaborations:**
  - Hyundai America Technical Center, Inc.
  - Halla Visteon Climate Control Corp.
  - Sekisui Chemical Company, Ltd.
  - Pittsburgh Glass Works, LLC.
  - PPG Industries, Inc.
  - Gentherm Incorporated
  - 3M Company
- **Project lead:**
  - National Renewable Energy Laboratory

# Relevance

## THE CHALLENGE

- 2014 light-duty vehicle (LDV) fuel use estimated at approximately 3 billion barrels oil<sup>1</sup>
- Increased market penetration of EDVs requires overcoming
  - Original equipment manufacturer (OEM) risk adversity in adopting new technologies
  - Limited vehicle range and associated customer range anxiety
  - Elevated cost of EDVs in comparison to existing conventional vehicles
- Climate control loads can significantly impact EDV range



1. Data Source: EIA Annual Outlook 2014 <http://www.eia.gov/forecasts/aeo/data.cfm>, accessed April 2015

2. Data Source: Argonne National Laboratory's Advanced Powertrain Research Facility

# Relevance

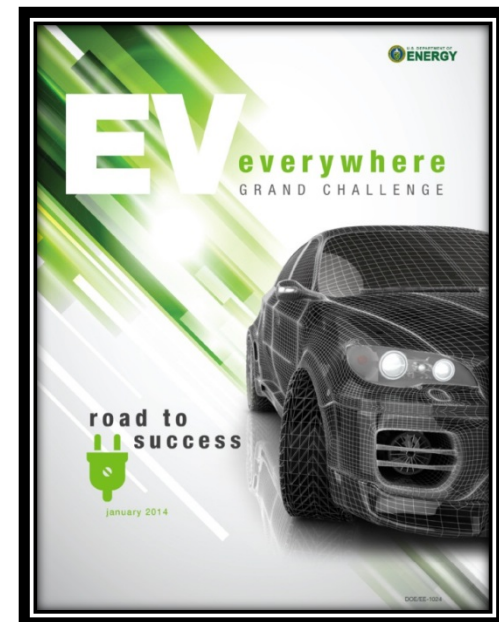
## THE OPPORTUNITY

- Reducing climate control loads can increase vehicle range to
  - Enable battery sizing and cost reductions
  - Reduce climate control equipment sizing
  - Enable advanced heating, ventilation, and air conditioning (HVAC) component technologies
- Load reduction system demonstration decreases OEM risk for adoption
- HVAC load reduction and advanced climate control design can positively impact occupant comfort



## Alignment with DOE VTP

- Support vehicle systems key goals for 2011–2015 Program Plan:  
*By 2015, develop technologies and a set of options to enable up to 50% reduction in LDV petroleum-based consumption*
- Support meeting EV Everywhere Grand Challenge targets



# Relevance

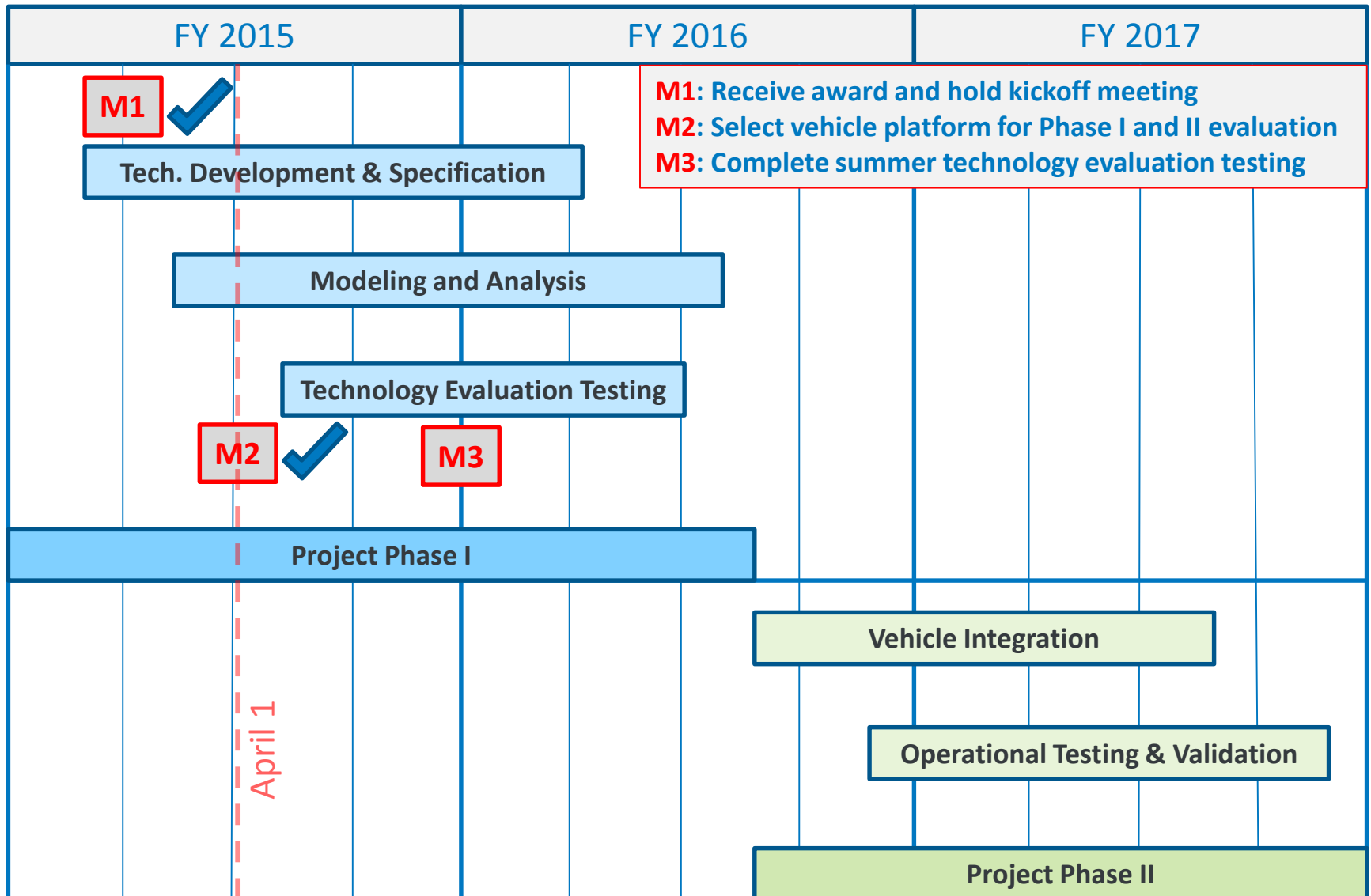
## THE GOAL

Increase grid-connected electric drive vehicle range by 20% during the operation of the climate control system over the standard vehicle configuration by reducing vehicle thermal loads

- Design and implement the thermal load reduction system on a production drivable vehicle
- Test the range impact over the combined city/highway drive cycle at peak heating and cooling conditions
- Maintain occupant thermal comfort in implemented system

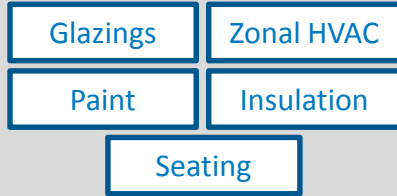


# Milestones 2015



# Approach – Two-Phase Process

*Individual Technologies*



*Individual Technology Performance*

**Design and Development**

Testing

Analysis

*Down-Selected Technologies*

**Integration and Validation**

Testing

Analysis

*National Results & Occupant Comfort*

*Full System Impact on Range*

*Validated Models*

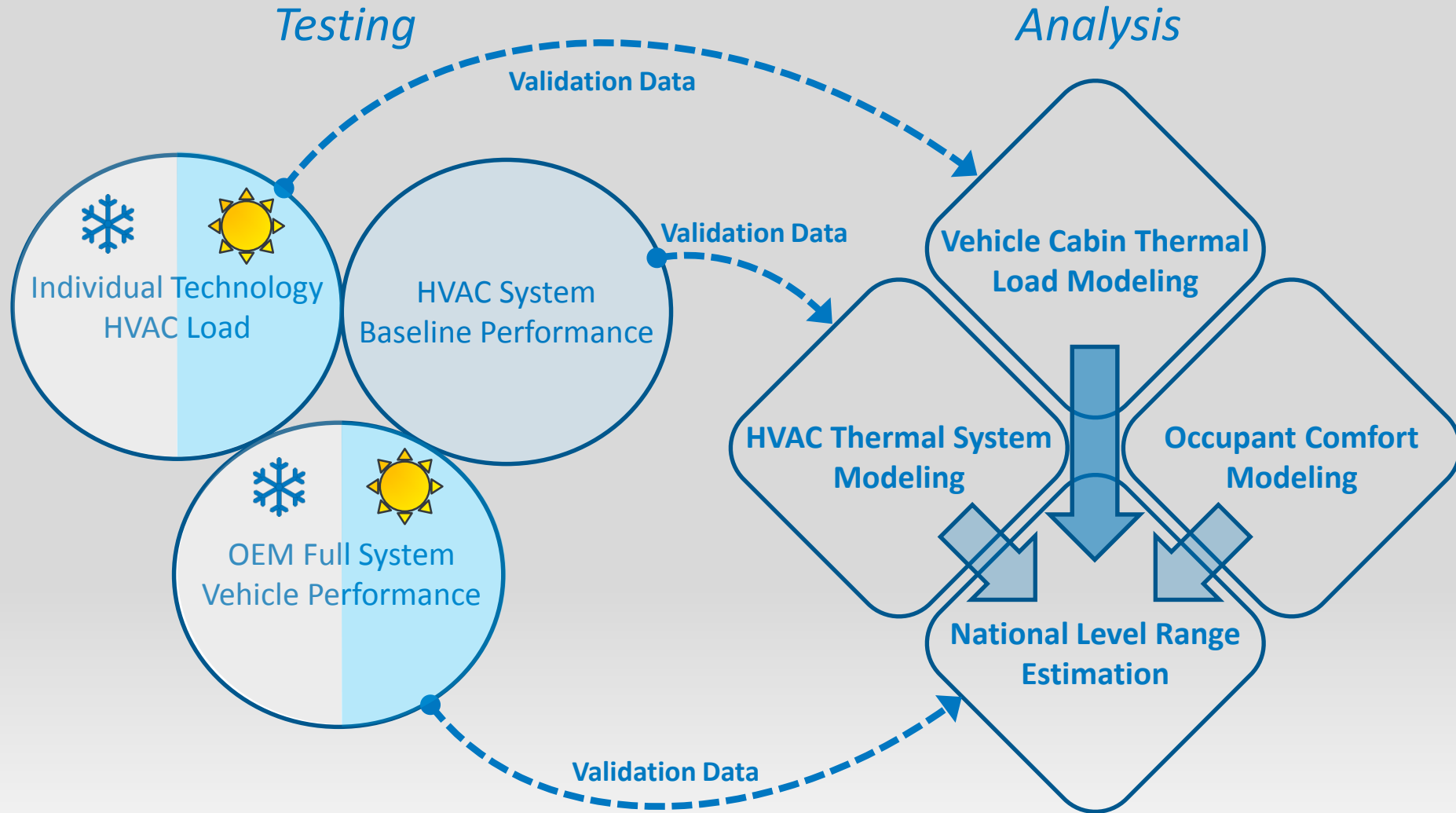
*Phase I*

*Technology Go/No-Go*

*Phase II*



# Approach – Testing and Analysis Strategy



Relevance

Approach

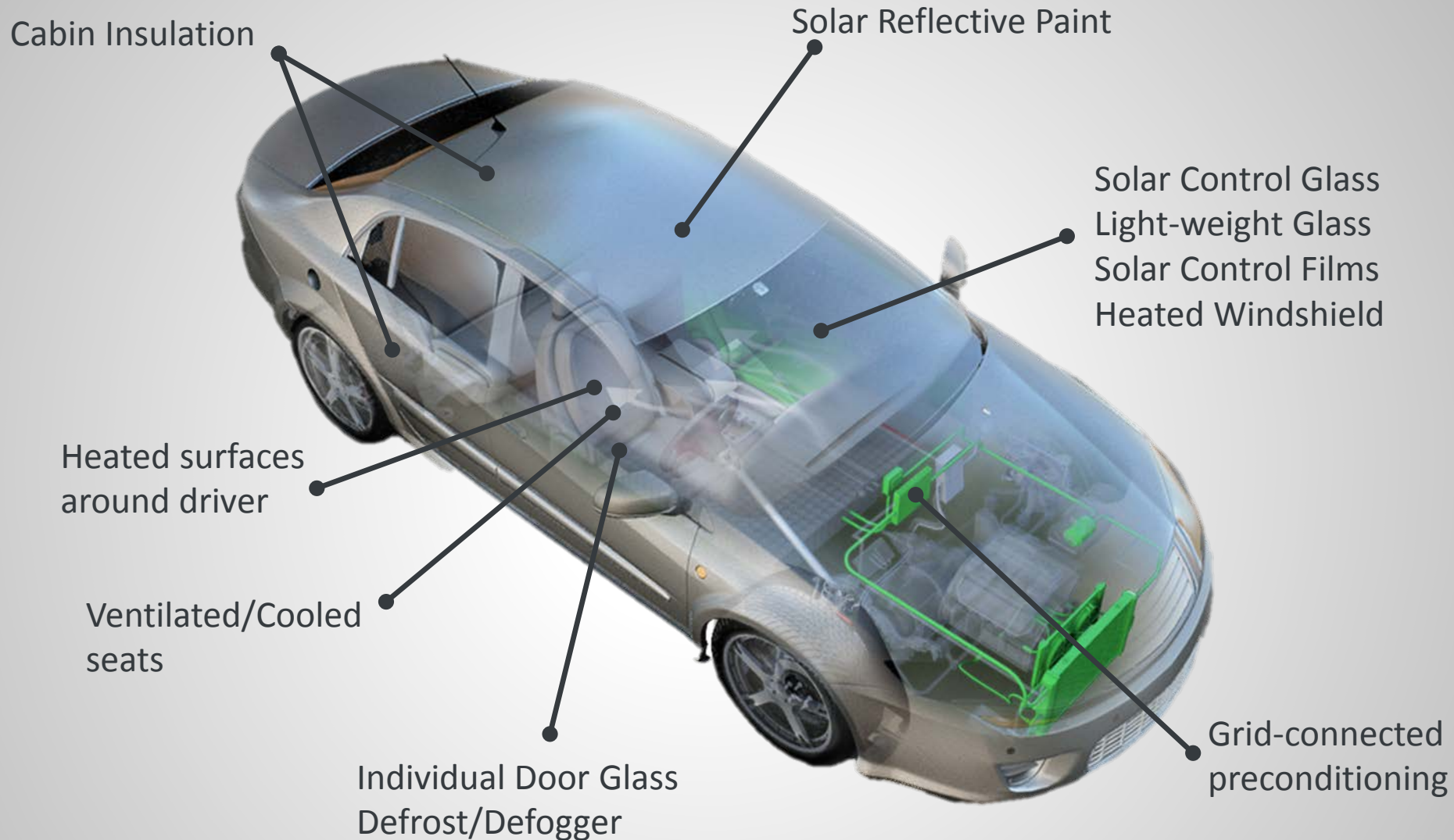
Accomplishments

Collaborations

Future Work



# Approach – Technology Areas



Relevance

Approach

Accomplishments

Collaborations

Future Work

# Accomplishments – Business

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- **Completion of legal obligations between all parties involved**
  - Multiparty nondisclosure agreement
  - Intellectual property management plan
- **Subcontracts for the following project partners (in progress as of April 1, 2015):**
  - Hyundai America Technical Center, Inc.
  - Pittsburgh Glass Works
  - Halla Visteon Climate Control
  - PPG Industries
  - Sekisui

# Accomplishments – Vehicle Platform Selection



















- The 2016 Hyundai Sonata plug-in hybrid electric vehicle (PHEV)\* was chosen to be the vehicle platform for both Phase I and Phase II evaluation and modeling
  - Prototype vehicles will be used for Phase I and production vehicles for Phase II
- \* Photos above are of the 2015 Hyundai Sonata conventional vehicle

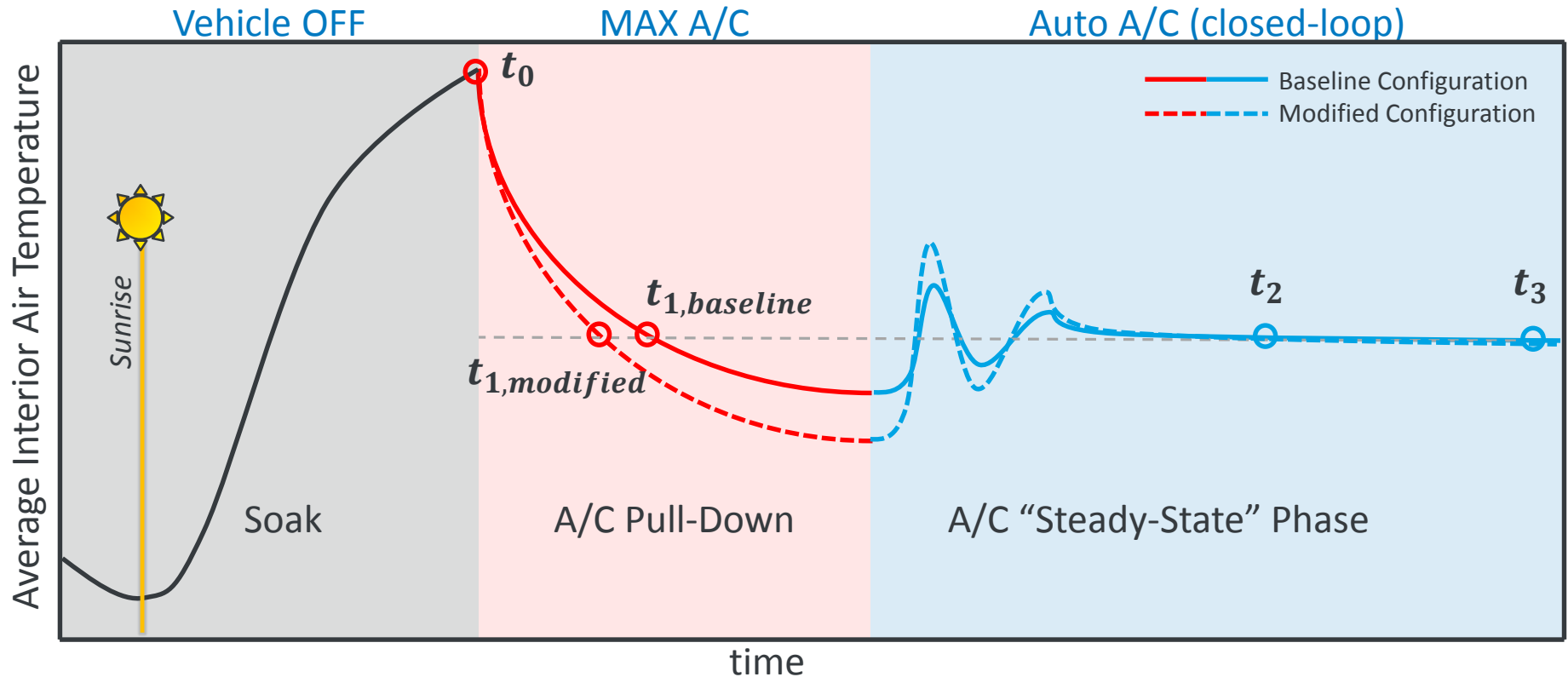
# Accomplishments – Phase I Preliminary Summer Test Plan

 Two-phase air conditioning test  
(pull-down & steady-state)

 Vehicle Cabin Solar  
Thermal Soak Evaluation

Configuration	May	June	July	August	September
Baseline & North Facing	 				
Insulation – Full & Partial		 			
Precondition					
Baseline – Max Loads			 		
Glass Packages			 	 	
Ventilated/ Cooled Seats					
Solar Reflective Paint					 
Combined Technologies					 

# Accomplishments – Phase I Summer A/C Test Approach



- Split two-component A/C test approach: pull-down and steady-state
- Energy use calculated as cumulative energy during each time interval
- Decoupled pull-down and steady-state components expected to increase repeatability and isolate technology impact on HVAC loads

# Response to Previous Year Reviewer's Comments

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**This is the first year of this project and therefore does not have previous year reviewer comments.**



# Collaboration and Coordination

## Hyundai America Technical Center

- Subtier Industry Partner
- Automotive OEM Supplier
- Lead on Phase II Technology Integration
- Lead on Phase II Full System Experimental Evaluation
- Technology Supplier (Collaboration with Gentherm)

## Pittsburgh Glass Works

- Subtier Industry Partner
- Glass Package Manufacturer
- Advanced Glass Technology Supplier

## PPG Industries

- Subtier Industry Partner
- Automotive Paint Supplier
- Advanced Paint Technology Supplier

## Halla Visteon Climate Control

- Subtier Industry Partner
- Baseline HVAC System Experimental Evaluation
- HVAC System Modeling Support
- HVAC System Control Support

## Sekisui

- Subtier Industry Partner
- Advanced Glass Technology Material Supplier

## Gentherm

- Subtier Industry Partner – In Kind
- Door Defrost/Defog Technology Supplier
- Heated Surfaces Technology Supplier (collaboration)
- Advanced Seating Technology Supplier (collaboration)

## 3M

- Subtier Industry Partner – In Kind
- Advanced Solar Control Film Supplier
- Advanced Insulation Technology Supplier



# Proposed Future Work

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## Phase I: Technology Design and Development (FY15–16)

- Complete summer and winter technology evaluation
- Complete baseline HVAC system performance characterization for HVAC model development
- Continue human comfort, HVAC system, and vehicle modeling for technology evaluation(s) and development of national level framework
- Perform Phase I technology evaluation Go/No-Go for Phase II

## Phase II: Technology Integration and Validation (FY16–17)

- Integrate thermal load reduction technologies into drivable vehicle system
- Perform operational cold weather, hot weather, and environmental chamber testing at Hyundai America Technical Center facilities
- Refine models with individual technology experimental results and perform national level analysis
- Final vehicle demonstration and project summary presentation to DOE

# Summary

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- The project's focus is to implement a thermal load reduction system into a GCEDV production vehicle in order to demonstrate the combined impact of previous and current work in this research area
- Key industry partners enable production-ready and cost-effective technologies and vehicle-level integration
- A combination of load reduction technologies and zonal climate control strategies are used to meet project goals
- Testing and modeling/analysis are used synergistically to quantify system performance and national relevance

# Summary

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## Accomplishments

- Initiated project with kickoff meeting and coordination on completion of multi-party NDA and IPMP documents
- Subcontract negotiations are in progress (as of April 1, 2015) for five subtier partners
- The 2016 Hyundai Sonata PHEV has been selected for the project vehicle platform
- Phase I summer test planning has been completed and A/C testing procedure identified

# Acknowledgements and Contacts

## Special thanks to:

- David Anderson and Lee Slezak  
*Vehicle and Systems Simulation  
and Testing*

## For more information:

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